

Journal: *Translational Andrology and Urology*

Manuscript ID: TAU-2018-MITKS-09

doi: 10.21037/tau.2019.08.16

Title: Latest advancements in ureteral stent technology

Corresponding author: Ali Mosayyebi

Dear Dr. Mosayyebi,

The proof of your manuscript is attached on the following pages. Please read through the document carefully to check for accuracy, reference citations, and figures and tables. Please also be aware a professional copyeditor may have edited your manuscript to comply with the TAU style requirements.

In addition to proofing the article, the following queries have arisen during the preparation of your paper. Please address the queries listed below by making the appropriate changes in the text.

If you have any other revisions that you would like to make, this will be the last opportunity to do so before the article is published. In particular, please ensure that the author's names and affiliations have been identified correctly, and the address of the corresponding author is correct.

If the changes cannot be easily described through email, please annotate this proof according to the annotation guidelines as detailed on the following page.

Query Reference	Query	Author's response
Q1	Please note that alterations cannot be made after you have approved for publication, irrespective of whether it is Online First.	
Q2	Author SURNAMES (family names) have been highlighted in red - please check that these are correct.	
Q3	Please check affiliations, correspondence details and contributions.	
Q4	Please check acknowledgements section and confirm the disclosure.	
Q5	Please note that the link with the DOI number for the manuscript should be valid only after the whole issue is officially published.	
Q6	Refs. 14-18: please provide these websites to check them.	

Once you have completed your revisions and/or addressed all the queries, or if you are satisfied with the proof in its existing form, please email: e-proof@amegroups.com.

**To ensure the timely publication of your article,
please respond within 48 hours.**

Making corrections

Use Adobe Reader – available for free from <http://get.adobe.com/reader/> – to open the attached document.

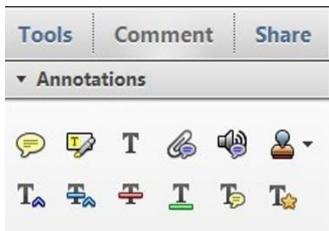


Figure 1 Adobe Acrobat X

Adobe Professional 7:

Tools → Commenting → show Commenting Toolbar

Adobe Reader 8:

Tools → Comments & Markup → show Comments and Markup Toolbar

Adobe Reader 10 and above:

Comment → choose either Sticky Note or Highlight Text

In-text edits	Select the appropriate symbol and then click and drag over the text to be modified. Replace : denotes where the text should be replaced with an alternative option Strikethrough : crosses out the text Underline : underlines the text Add note to text : links selected text with a pop-up note
Sticky notes	To make a note: choose the Sticky Note option and then click on a desired location Changing the name: double-click and choose Options → Sticky Note Properties → General → insert desired name To move: click anywhere (apart from the text field) and drag To resize: click on the right or left hand order and drag To close: click the box on the upper right corner; this does NOT delete your note To delete: click and press the Delete keyboard button or right click and select delete from the drop-down menu
Highlighting	This allows you can highlight parts of the text. To highlight: select Highlight and then click and drag over the text to be highlighted. When finished, click on Highlight again to turn off the option. To change the colour: double-click on the highlighted text and choose Options → Properties → Appearance → Color

Saving your changes:

Click on *File → Save* before closing the document.

For more detailed instructions on using Adobe Acrobat, please refer to

<http://www.adobe.com/support/acrobat/gettingstarted/>

Latest advancements in ureteral stent technology

Antonio De Grazia^{1,2}, Bhaskar K. Soman³, Federico Soria⁴, Dario Carugo^{1,2}, Ali Mosayyebi^{1,2}

¹Bioengineering Science Research Group, Faculty of Engineering and the Environment, ²Institute for Life Sciences (IfLS), University of Southampton, Southampton, UK; ³Department of Urology, University Hospital Southampton NHS Trust, Southampton, UK; ⁴Department of Endoscopy-Endourology, Minimally Invasive Surgery Centre-Jesus Usón, Cáceres, Spain

Contributions: (I) Conception and design: A De Grazia, A Mosayyebi; (II) Administrative support: BK Soman, F Soria, D Carugo; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: A De Grazia, A Mosayyebi; (V) Data analysis and interpretation: None; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Ali Mosayyebi. Bioengineering Science Research Group, Faculty of Engineering and the Environment and Institute for Life Sciences (IfLS), University of Southampton, Southampton, UK. Email: a.mosayyebi@soton.ac.uk.

Abstract: Urological diseases such as tumours, kidney stones, or strictures in the ureter can lead to a number of health consequences, including life-threatening complications. Ureteral stents have been widely used as a valid solution to restore compromised urological function. Despite their clinical success, stents are subject to failure due to encrustation and biofilm formation, potentially leading to urinary tract infection. The current review focuses on recent advancements in ureteral stent technology, which have been reported in recent scientific journals or patents. Web of Science and Google Scholar have been used as a search engine to perform this review, using the keywords including but not limited to “Ureteral + Stent + Design”, “Ureteral + Stent + Material + Coating”, “Ureteric + Stent” and “Ureteral + Stent”. A significant proportion of technological developments has focused on innovating the stent design to overcome migration and urinary reflux, as well as investigating novel materials and coatings to prevent biofilm formation, such as poly(N,N-dimethylacrylamide) (PDMMA) and swellable polyethylene glycol diacrylate (PEGDA). Biodegradable ureteral stents (BUS) have also emerged as a new generation of endourological devices, overcoming the “forgotten stent syndrome” and reducing healthcare costs. Moreover, efforts have been made to develop pre-clinical test methods, both experimental and computational, which could be employed as a screening platform to inform the design of novel stent technologies.

Keywords: Ureteral stents; reflux; migration; biofilm; encrustation; computational fluid dynamics (CFD); design; material; test

Submitted Jan 25, 2019. Accepted for publication Jun 28, 2019.

doi: 10.21037/tau.2019.08.16

View this article at: <http://dx.doi.org/10.21037/tau.2019.08.16>

1 Introduction

2 The upper urinary tract can become obstructed because
 3 of several physio-pathological conditions or diseases. The
 4 aetiology of obstruction can be intraluminal (i.e., due to
 5 renal or ureteral stones, ureteral strictures, or papillary
 6 urothelial neoplasms) or extramural (i.e., due to advanced
 7 urological or non-urological neoplasia). Ureteral blockages
 8 increase the ureteric backpressure and—if left untreated—
 9 can result in kidney failure. In 1960s, catheters made of
 10 silicone rubber were introduced as the first generation of
 11

12 ureteral stents and employed as a temporary measure to by-
 13 pass ureteric blockages. Since then, the stent technology
 14 has undergone many developments, encompassing the
 15 constitutive material, surface coating, and design of the
 16 stent. Currently, a typical stent architecture consists of a
 17 22–24 cm long flexible tube made of polymeric or metallic
 18 materials, with side-holes punched alongside its body. The
 19 two extremities of the stent are J-shaped (also known as pig-
 20 tail ends) and are designed to anchor the stent in the renal
 21 pelvis and bladder, thus preventing it from migrating (1) (see
 22 *Figure 1*).

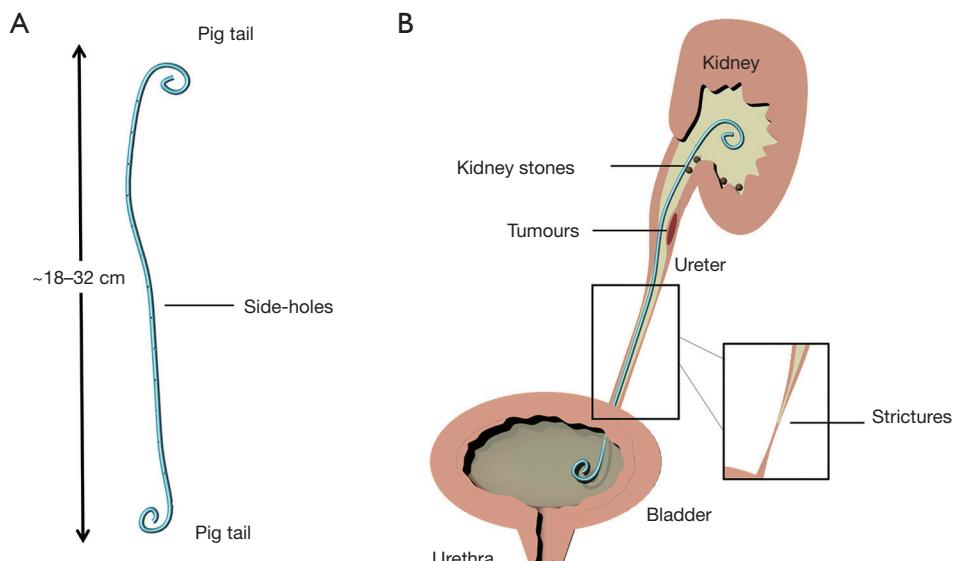


Figure 1 Ureteral stents are flexible tube-like devices with holes orthogonal to the length which allow for the passage of urine in case of ureteric obstruction. Pig tail ends in the stent help reducing migration of the stent and are located in the kidney and in the bladder. (A) A standard ureteral stent highlighting its key features (pig-tail ends and side-holes); (B) a cartoon of the urinary system illustrating common causes of ureteric obstruction and the placement of a double-J stent.

23 Over 1.5 million ureteral stents are used every year
 24 worldwide; however, it is estimated that >80% suffer
 25 from failure, which can cause severe pain and negatively
 26 impact on a patient's quality of life, may require surgical
 27 re-intervention, and ultimately increase the healthcare
 28 economic burden (2,3). Some of the underlying causes
 29 of failure are ureterovesical reflux, tissue irritation, and
 30 formation of infectious crystalline biofilms (4,5).

31 Over the last few years, a large body of research has
 32 focused on innovating the stent technology, predominately
 33 through the development of materials and architectural
 34 features that may prevent or delay stent-associated
 35 complications. These have been discussed in recent review
 36 articles (6,7). In the present review, we highlight the very
 37 recent advancements in stent technology.

39 **Advances in the constitutive materials or 40 surface coatings**

41 Several composite materials have been investigated for
 42 application in endourological devices (6,8); however, their
 43 usage has not led to a significant reduction in the incidence
 44 of stent encrustation or biofilm formation (9). The following
 45 section highlights recent advances in the constitutive
 46 materials of the stent, which are also summarised in *Table 1*.

47 Szell *et al.* (10) developed a coating agent to prevent
 48 biofilm formation on stents, in the form of a poly(N,N-
 49 dimethylacrylamide) (PDMMA) hydrogel with antifouling
 50 and protein-repellent properties. In their study, bacterial
 51 proliferation and adhesion were evaluated in-vitro. The
 52 hydrogel layer was deposited on both polyurethane
 53 (PU) and cyclin olefin polymer (COP) glass slides,
 54 which were incubated in sterile human urine for 48 h.
 55 Uropathogens were then added to the medium and, after
 56 further incubation (24 to 48 h), bacterial proliferation was
 57 quantified by CFU counting. PDMAA coating on both
 58 PU and COP surfaces significantly decreased (5-fold) the
 59 presence of bacteria adhered on the surface.

60 Some commercially available stents (e.g., Universa®
 61 Soft Ureteral Stent; COOK® Medical, Bloomington,
 62 IN, USA) are coated with hydrophilic hydrogels (usually
 63 PVA) that become lubricious and reduce surface friction
 64 upon deployment. Hydrogels can also be utilised as a
 65 substrate to achieve controlled release of biologically active
 66 compounds. For instance, Lim *et al.* (11) developed a drug-
 67 eluting ureteric stent, allowing for a constant drug release
 68 over time (up to 4–6 weeks, *in-vitro*) which improves drug
 69 absorption by the urothelium. The stent is spray-coated
 70 with a blend of a biodegradable polymer (70/30 poly-L-
 71 lactide-co-caprolactone, PLC) and an anti-proliferative
 72

Table 1 Summary of key recent advances in ureteral stent design and materials, as well as stent characterisation methods

Improvement area	The change	Reference
Constitutive material	Coating agent for stent against biofilm formation (PDMMA)	Szell <i>et al.</i> (10)
	Drug-eluting and swellable stent (PEGDA)	Lim <i>et al.</i> (11)
	Biodegradable ureteral stent (BUS)	Barros <i>et al.</i> (12) & Soria <i>et al.</i> (13)
Stent design	Telescoping ureteral stent with anchoring system against migration	Pendleton <i>et al.</i> (14)
	Helical stent for controlling drainage	DeGraaf <i>et al.</i> (15)
	Non-coplanar pig-tails to avoid migration	Yachia <i>et al.</i> (16)
	J-tail in the kidney and anchoring structure in the bladder, to reduce reflux	McMahon <i>et al.</i> (17)
	Self-expandable mesh structure for anchoring in the bladder, and valve mechanism to prevent reflux	Shelton <i>et al.</i> (18)
Testing method	Mechanical testing: radial compression, self-expanding and self-stabilising, and friction	Yin <i>et al.</i> (19)
	Flow testing: in-house in-vitro model comprising serological pipettes shaped to accommodate stents	
	Constant and step compressive uniaxial loading to mimic extrinsic ureteric obstructions	Davis <i>et al.</i> (20)
	In-silico computational fluid dynamics (CFD) simulations replicating physiological properties, to minimise patient discomfort	Marzo <i>et al.</i> (21)
	Miniatrised experimental and CFD models replicating the obstructed urinary system, to design novel stent architectures against particle deposition	Mosayyebi <i>et al.</i> (23)

73 drug (mitomycin C, MMC). This layer is then coated with
 74 polyethylene glycol diacrylate (PEGDA) hydrogel. PEGDA
 75 is a swellable polymer, thus the size of this outer coating
 76 layer increases once the stent is deployed, reducing the
 77 gap between stent and urothelium (~1.5 mm). Moreover,
 78 the hydrogel layer prevents the drug from being rapidly
 79 washed away by the urine flow, and retains it in proximity
 80 to the stent. Such a stent could be potentially used for
 81 the treatment of diseases affecting the urothelium, such
 82 as tumours or strictures. A pilot *in-vivo* study in a porcine
 83 model also demonstrated that the stent inserts easily in the
 84 upper tract, does not damage the urothelium or compromise
 85 kidney function, and does not cause hydronephrosis or
 86 systemic toxicity.

87 One aspect of significant interest in the last year has been
 88 the evaluation of biodegradable ureteral stents (BUS) using
 89 porcine animal models *in-vivo*. Biodegradable stents present
 90 several benefits, such as decreased patient discomfort and
 91 anxiety, and reduction of healthcare costs (including those
 92 associated with the “forgotten stent syndrome”). They

93 are also particularly suitable for paediatric patients, to
 94 avoid anaesthesia during removal of the stent. BUS have
 95 been recently manufactured by Barros *et al.* (12), using an
 96 aqueous solution of gelatin-alginic-acid sodium salt and
 97 bismuth carbonate basic. Soria *et al.* (13) instead used a
 98 copolymer (Glycomer 631) and a polymer (polyglycolic
 99 acid). In both studies, BUS degradation took place in a
 100 controlled and predictable fashion, and no obstructive
 101 fragments appeared. Despite additional experiments are
 102 required to further validate this technology, it is evident
 103 that biodegradable stents represent an important avenue in
 104 future stent technology.

Advances in stent design

107 The development of novel stent designs has recently focused
 108 on stent architectures that could reduce tissue irritation
 109 and urinary reflux. The following section highlights recent
 110 advances in stent design (and their background claims),
 111 most of which have been patented. A summary of these
 112

113 inventions is also provided in *Table 1*.

114 Pendleton *et al.* (14) introduced a telescoping ureteral
 115 stent structure with the aim of improving stent patency;
 116 this design has been translated into a commercial device by
 117 COOK® Medical. It comprises a distal structure (located
 118 towards the kidney) telescopically sliding into a proximal
 119 structure (located towards the bladder). The invention
 120 also involves a number of new anchoring mechanisms
 121 that would act in two ways, (I) by stopping the stent
 122 from migrating inside the ureter and (II) by preventing
 123 the extended proximal end from returning back into the
 124 ureter. Additionally, novel deployment methods have been
 125 proposed for these stent models.

126 DeGraaf *et al.* (Boston Scientific Corporation, Grove,
 127 MN, USA) (15) introduced an helical stent made of
 128 polymeric materials, with the aim of controlling urine
 129 drainage through the stent. The embodiments of this
 130 invention consist of filaments with controlled extension
 131 properties, which are coiled around the stent lumen,
 132 together with a dissolvable coating. The degree of stent
 133 extension is defined based on the material stiffness, filament
 134 dimension, filament shape, and the method of extension.

135 Yachia *et al.* (Innoventions Ltd., Akiva, Israel) (16)
 136 invented a stent design that aims to reduce patient's
 137 discomfort and flank pain. It relies on having both pig-
 138 tail ends non-coplanar with respect to the bladder trigone.
 139 The proximal end consists of a sleeve made of a softer
 140 material, which allows controlling the expansion of the pig
 141 tail depending on the level of urine force compared to the
 142 sleeve radial tensile force. Additionally, they introduced
 143 different shapes of the proximal region with the aim of
 144 preventing urine reflux from the bladder towards the
 145 kidney, due to increased bladder pressure. Another design
 146 element is a pre-shaped wire (made of polymer or metal)
 147 that is inserted through a small lumen parallel to the main
 148 stent lumen, with the purpose of retaining the curly shape
 149 of the stent.

150 McMahon *et al.* (Baylor University, Texas, USA) (17)
 151 introduced a stent design with potential for reducing
 152 ureterovesical reflux. It includes a distal J-end (kidney) and
 153 a novel anchoring structure at the proximal end (bladder).
 154 The lumen is designed to have a narrower cross-section
 155 in the bladder, in order to reduce bladder irritation. This
 156 segment of the stent could be expanded or folded depending
 157 on the level of anchoring required. Moreover, a flapper
 158 valve was designed at the bladder end, which closes when
 159 the bladder pressure increases in order to prevent reflux.

160 Shelton *et al.* (Gyrus ACMI®, Massachusetts, USA) (18)

161 introduced a series of ureteral stent designs, with the aim
 162 of reducing urothelial tissue irritation, particularly at the
 163 bladder trigone and the uretero-vesical junction (UVJ).
 164 This design concept relies on projections (with different
 165 shape, length, size, and orientation), a self-expandable
 166 mesh structure anchoring in proximity to the UVJ, and
 167 coiled tails which may have a different internal diameter
 168 compared to the ureteric section of the stent. The invention
 169 also includes the integration with a valving mechanism to
 170 prevent reflux.

Pre-clinical testing of stent function

173 Yin *et al.* (19) introduced a novel stent manufacturing
 174 technology based on freeze-casting, in order to generate
 175 porous stents with improved urine drainage. In their study,
 176 stents manufactured with this technique were compared to
 177 standard 8 Fr double-J stent (Universa® Soft Ureteral Stent
 178 with Hydrophilic Coating, Cook® Medical, Bloomington,
 179 IN, USA). To understand the surface structure, both types
 180 of stent were imaged by scanning electron microscopy
 181 (SEM) and confocal microscopy, to characterise transverse
 182 and longitudinal sections, and both inner and outer surfaces
 183 of the stent. Mechanical testing was performed, including
 184 radial compression, self-expanding and self-stabilising
 185 testing, and friction testing (to determine the friction force
 186 due to a known displacement rate of 0.01 mm/s). The flow
 187 performance of the stent was investigated using an in-vitro
 188 model developed in house, comprising serological pipettes
 189 that were shaped to accommodate a stent. Results from
 190 these tests showed that the porous stent had improved
 191 drainage compared to the standard one.

192 Davis *et al.* (20) developed a method to investigate the
 193 ability of stents to resist extrinsic ureteric obstructions. It
 194 relies on the application of a constant or step compressive
 195 uniaxial loading in a direction orthogonal to the stent axis,
 196 at three different locations (proximal, central, and distal).
 197 Two types of load were investigated which were applied
 198 through (I) a 625 mm² square surface simulating a large
 199 extrinsic obstruction, and (II) a metal rod (1 mm radius) to
 200 simulate a confined obstruction.

201 Marzo *et al.* (21) introduced an efficient urinary
 202 drainage test system, specifically designed for urethral
 203 catheters. They employed theoretical analytical method,
 204 computational fluid dynamics (CFD) simulations and a
 205 standard experimental design to investigate the effect of
 206 catheter diameter on urinary drainage, with the ultimate
 207 goal of identifying a catheter design that could reduce

209 patient discomfort. Their theoretical model was designed to
 210 replicate the physiological properties of the urinary system,
 211 specifically bladder and urethral region (geometry and flow
 212 dynamics of the urine flow through a bent tube). Results
 213 show that reducing the catheter inner diameter by half of its
 214 original size would significantly improve clinical tolerability
 215 while maintaining an acceptable flow rate. Moreover, the
 216 CFD simulation package allowed investigating the effect of
 217 catheter design changes on the spatial distribution of wall
 218 shear stress (WSS) and urine velocity.

219 The utility of CFD modelling as a tool to innovate stent
 220 design is also evident in the work by Mosayyebi *et al.* (22).
 221 In their earlier study (23), they developed a microfluidic
 222 platform (known as 'stent-on-chip') to investigate the
 223 mechanism of particle accumulation in ureteric stents.
 224 Using this model, they demonstrated an inverse correlation
 225 between the magnitude of shear stress acting on the
 226 stent surface (computed from CFD simulations) and the
 227 accumulation of encrusting particles. Moreover, they
 228 identified regions of the stent that are more likely to suffer
 229 from encrustation, such as inactive side-holes and other
 230 stagnant regions in the vicinity of a ureteric obstruction.
 231 Results qualitatively agreed with observations on stents
 232 retrieved from patients. Building upon this study, the
 233 same group investigated changes to the stent geometry,
 234 by varying the stent wall thickness and the shape of side-
 235 holes. They concluded that a thinner stent with streamlined
 236 side holes offers a 90% reduction in particle deposition
 237 compared to a standard stent design.

238

239 Conclusions

240 The present manuscript reviews recent developments in
 241 stent technology, with a focus on stent material, design,
 242 and characterisation methods. The most notable advances
 243 in stent materials include antibacterial and drug-eluting
 244 coatings, and biodegradable stents. Innovations in the stent
 245 design focused on reducing ureterovesical reflux, stent
 246 migration, and tissue irritation.

247 Despite significant efforts have been devoted to the
 248 improvement of current stent technologies, an ideal stent
 249 that does not suffer from failure and complications does
 250 not yet exist. However, we anticipate that this could be
 251 achieved through simultaneous developments of multiple
 252 technological features and properties of a stent, and by
 253 establishing appropriate computational and experimental
 254 design optimisation and verification procedures.

Acknowledgments

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest
 to declare.

Ethical Statement: The authors are accountable for all
 aspects of the work in ensuring that questions related
 to the accuracy or integrity of any part of the work are
 appropriately investigated and resolved.

References

1. Albala DM, Gomella LG, Morey AF, et al. Oxford American handbook of urology. Oxford University Press; 2010:571-658.
2. Davenport K, Kumar V, Collins J, et al. New Ureteral Stent Design Does Not Improve Patient Quality of Life: A Randomized, Controlled Trial. *J Urol* 2011;185:175-8.
3. Harber M. Practical Nephrology. Springer; 2014:439-52.
4. Urinary Stone Disease: The Practical Guide to Medical and Surgical Management (Current Clinical Urology). 2007 ed. Current Clinical Urology. Humana Press; 2007.
5. Keane PF, Bonner MC, Johnston SR, et al. Characterisation of biofilm and encrustation on ureteral stents in-vivo. *Br J Urol* 1994;73:687-91.
6. Mosayyebi A, Manes C, Carugo D, et al. Advances in Ureteral Stent Design and Materials. *Curr Urol Rep* 2018;19:35.
7. Chew BH, Lange D. Advances in ureteral stent development. *Curr Opin Urol* 2016;26:277-82.
8. Mosayyebi A, Vijayakumar A, Yue QY, et al. Engineering solutions to ureteral stents: material, coating and design. *Cent European J Urol* 2017;70:270.
9. Cauda V, Chiodoni A, Laurenti M, et al. Ureteral double-J stents performances toward encrustation after long-term indwelling in a dynamic in vitro model. *J Biomed Mater Res B Appl Biomater* 2017;105:2244-53.
10. Szell T, Dressler FF, Goelz H, et al. In Vitro Effects of a Novel Coating Agent on Bacterial Biofilm Development on Ureteral Stents. *J Endourol* 2019;33:225-31.
11. Lim WS, Chen K, Chong TW, et al. A bilayer swellable drug-eluting ureteric stent: Localized drug delivery to treat urothelial diseases. *Biomaterials* 2018;165:25-38.
12. Barros AA, Oliveira C, Ribeiro AJ, et al. In vivo assessment

304 of a novel biodegradable ureteral stent. *World J Urol* 321
 305 2018;36:277-83.

306 13. Soria F, Morcillo E, Serrano A, et al. Evaluation of a new 322
 307 design of antireflux-biodegradable ureteral stent in animal 323
 308 model. *Urology* 2018;115:59-64.

309 14. Pendleton SL, Neff GL, Biltz BT. Telescoping ureteral 324
 310 stent. *Google Patents*; 2018.

311 15. DeGraaf K, Harrah TP, Boden MW, et al. Controlled 325
 312 extension stent. *Google Patents*; 2018.

313 16. Yachia D, Ponomarenko V. Stent and Method of Use. 326
 314 *Google Patents*; 2018.

315 17. McMahon CW, Nief CA, Schmidt DR, et al. Ureteral 327
 316 stent and method. *Google Patents*; 2018.

317 18. Shelton KG, Prats AE. Ureteral stent with anti-migration 328
 318 features. *Google Patents*; 2018.

319 19. Yin K, Divakar P, Wegst UG. Freeze-casting porous 329
 320 chitosan ureteral stents for improved drainage. *Acta 330*
Biomater 2019;84:231-41.

20. Davis NF, Mulvihill JJE, Lynch JJ, et al. Digital and 331
 Mechanical Characterization of Ureteral Stent Luminal 332
 Reduction in Response to Extrinsic Compression Forces. *J 333*
Endourol 2018;32:1148-53.

21. Marzo A, Melis A, Unger J, et al. An engineering approach 334
 towards a more discrete and efficient urinary drainage 335
 system. *Proc Inst Mech Eng H* 2019;233:58-67.

22. Mosayyebi A, Lange D, Yann Yue Q, et al. Reducing 336
 deposition of encrustation in ureteric stents by changing 337
 the stent architecture: A microfluidic-based investigation. 338
Biomicrofluidics 2019;13:014101.

23. Mosayyebi A, Yue QY, Somani BK, et al. Particle 339
 Accumulation in Ureteral Stents Is Governed by Fluid 340
 Dynamics: In Vitro Study Using a "Stent-on-Chip" 341
 Model. *J Endourol* 2018;32:639-46.

Cite this article as: De Grazia A, Somani BK, Soria F, Carugo D, Mosayyebi A. Latest advancements in ureteral stent technology. *Transl Androl Urol* 2019. doi: 10.21037/tau.2019.08.16